Effects of microabrasion on substance loss, surface roughness, and colorimetric changes on enamel in vitro

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Abstract: OBJECTIVES: To determine in vitro the effects of 2 commercially available microabrasion compounds (Prema [Premiere Dental Products] and Opalustre [Ultradent]) on human enamel under standardized conditions after treatment periods of 10, 20, 30, and 40 seconds. Nonacidified pumice served as an abrasive control compound. METHOD AND MATERIALS: Mean substance loss was determined by measuring dissolved Ca2+ using atomic absorption spectrophotometry. Differences in the mean surface roughness were profilometrically assessed. These findings were completed with micromorphologic observations using SEM. In addition, color changes after microabrasion were evaluated using the CIE L*a*b* system. RESULTS: Opalustre caused the highest tooth substance loss, followed by the Prema compound and pumice, which showed a lesser substance-removal capacity. These findings were in concordance with the mean surface roughness difference measurements and micromorphologic analyses. Microabrasion did not cause any significant colorimetric changes. CONCLUSION: Microabrasion should be considered a microinvasive method, and clinical application should be used with caution to avoid excessive substance removal. Subsequent polishing appears crucial to maintain optimal esthetics and avoid surface alterations.

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Effects of microabrasion on substance loss, surface roughness, and colorimetric changes on enamel *in vitro*

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Abstract

Objectives: This laboratory study aimed to determine the effects of two commercially available microabrasion compounds (Prema® and Opalustre®) on human enamel under standardized conditions after treatment periods of 10, 20, 30 and 40 seconds, respectively. Non-acidified pumice served as abrasive control compound.

Method and materials: Mean substance loss was determinded by measuring dissolved Ca^{2+} using atomic absorption spectrophotometry. Differences in the mean surface roughness were profilometrically assessed. These findings were completed with micromorphologic observations using SEM. In addition, color changes after microabrasion were evaluated using the CIELab-system.

Results: Opalustre® caused the highest tooth substance loss followed by the Prema® compound and pumice, which showed a lesser substance removal capacity. These findings were in concordance with the mean surface roughness difference measurements and micromorphologic analyses. Microabrasion did not cause any significant colorimetric changes.

Conclusion: It was concluded that microabrasion should be considered a "micro-invasive" method and that clinical application should be used with caution to avoid excessive substance removal. Subsequent polishing appears crucial to maintain optimal esthetics and avoid surface alterations.

Clinical relevance: Clinicians must be aware of the abrasive potential of different microabrasion materials and concisely evaluate this so-called micro-invasive treatment. Surface alterations need additional polishing. Color changes of the mineralized tissues, however, are not to be expected.

INTRODUCTION

Enamel microabrasion has become accepted as a conservative, non-restorative method to improve the appearance of teeth with superficial dysmineralisation and decalcification defects.[1] Croll coined the term *dysmineralisation* for coloration defects that result from abnormality in the formation of the inorganic component of enamel during amelogenesis.[2] Removal of superficial enamel discolorations is commonly based on mild acid etching in combination with rotary application of an abrasive medium. For a review of this technique the authors refer to Tudts *et al*..[3] There are two methods for microabrasion. The first uses an in-office made mixture of 18% hydrochloric acid and pumice, which is applied to the surface with either a tongue blade or a rubber cup. The second method uses commercially produced hydrochloric acid / abrasive medium mixtures.

Although this method and the commercially available products are widely used clinically, only limited data are available on their effects on teeth.

Several mechanisms have been proposed. The stained outer layer of enamel is physically removed by abrasion and erosion. Waggoner *et al*.[4] reported an average of 12 µm of material removed after the initial application, and an average of 26 µm of enamel loss after each successive application when using an 18% HCl-pumice mixture. Tong *et al*.[5] quantified the loss of surface enamel using the same mixture and a rotary prophy cup at up to 360 µm, showing that the effect is time dependent. In addition, microabrasion reportedly changes the optical characteristic of the enamel surface, which may be explained by an effect on inorganic and/or organic enamel components caused by the penetration of the acid component.

Therefore, it was the aim of the present *in vitro* study to investigate the enamel removal capacity, surface roughness and micromorphological canges of three different products under standardized conditions. Color changes were evaluated using the CIELab-system. The hypothesis tested was

that the acidified microabrasive products under investigation would lead to significantly increased substance loss, surface alterations and color changes as compared to the non-acidified control material.

METHOD AND MATERIALS

Thirty extracted human upper central incisors were stored in 0.1% thymol solution before use. Their buccal surfaces were carefully examined for the presence of any enamel developmental defect or irregularity. The crowns were separated from the roots 1 mm below the cemento-enamel junction and embedded by the palatal surface in chemically curing acrylic resin (Paladur®, Heraeus Kulzer GmbH, Wehrheim, Germany). The labial surfaces were polished consecutively with 15 µm and 3 µm disks (SOF-LEX Pop-On-Discs 1982SF15 and XT3281SF; 3M Corp., St. Paul, MI, USA), mounted on a mandrel (3M Corp.) in a slow speed contra angle hand piece (Micro Mega, Genève-Acasias, Switzerland), with water-cooling, at a load of 30 g for 1 min. The polishing load was measured using an 8600 digital multimeter (Kontron Electronic AG, Zürich, Switzerland). A round area with a diameter of 5 mm was defined using punched adhesive tape (Netztech Handels AG, Baar, Switzerland).

Specimens were randomly allocated to 3 treatment groups (n=10 each) according to the abrasive media used :

Pumice (Pumex S.p.A. Porticello, Italy, control), Prema® (Premiere Dental Products Co, USA) and Opalustre® (Ultradent Prod. Inc., Utah, USA). Chemical composition and specifications are reported in Table 1. Micromorphological SEM images of the abrasive slurry particles at a magnification of 200x are presented in Fig. 1.

Treatment was performed using rubber cups (OpalCups, Ultradent Products Inc.) and the enamel microabrasion slurries at 300 rpm in 10-second intervals for 10, 20, 30 and 40 seconds,

respectively, using a slow contra angle hand piece (120 IS Micro Mega, Besançon, France) and a standardized force of 100 g, monitored using an 8,600 digital multimeter specification control device (Kontron Electronic, Zurich, Switzerland).

At baseline and after each treatment interval, the following parameters were assessed as described in more detail below:

Substance loss, surface roughness, surface morphology and color changes.

Measurement of substance loss

Loss of substance was detected using atomic absorption spectrophotometry (AAS). After each 10-second treatment interval, dentin particles were collected by rinsing specimens and cups with 10 ml of distilled water each. Collected sample solution was diluted with 10 ml of hydrochloric acid (2M). The specimen solutions were placed in an ultrasonic bath for five minutes to dissolve the insoluble dentin particles and to avoid precipitation. Aqua destillata was added to an end volume of 50 ml; 2 ml of the solution was extracted and 4.6 ml distilled water, as well as 3.4 ml $SrCl_3$ complimented the solution for AAS analysis (PERKIN ELMER 2380, Dietikon, Switzerland). The calcium was determined from standard solutions in ppm.

Profilometric and SEM analyses

Before the first and after each consecutive 10-second interval of instrumentation, specimens were washed and dried. An impression was taken using an addition-type polvinylsiloxane of low viscosity (President light body, Coltène AG, Altstätten, Switzerland) and replicas (Stycast®, Emerson & Cuming, Westerlo, Belgium) of the surfaces were cast. The average surface

roughness (Ra) was quantified with a computerised profilometer (Form Talysurf 50, Rank Taylor Hobson, Leicester, England).

In addition, the replicas were glued to SEM mounts (Balzers Union AG, Balzers, Liechtenstein) with superglue (Renfert Sekundenkleber Nr. 1733, Dentex AG, Zurich, Switzerland). The mounted replicas were gold sputtered and analysed under the SEM (AMRAY 1810, Welter, Germany) to assess the surface morphology of the enamel before and resulting after instrumentation at magnifications of 200x.

Color measurements

At baseline and after each 10-second intervals, the color of each specimen was assessed according to the CIELab-System with a spectrophotometer under standardised conditions (CM 3500d, Minolta AG, Dietikon, Switzerland). Therefore, specimens which were carefully dried for 5 seconds (not desiccated), were placed in a dark box so that the measurement tip of the spectrophotometer was always directed towards the identical point on the surface of the respective sample at all measurements performed. The spectrophotometer recorded the *L-, a-* and *b-* values. The differences (ΔL, Δa and Δb) between the initial readings and the respective final values were calculated.

The following color definitions for the respective positive (+) and negative (-) values were defined:

ΔL = (+) white, (-) black; Δb = (+) yellow (-) blue; Δa = (+) red, (-) green

Statistical analysis

Statistical differences were checked by analysis of variance. If differences were found between groups, the Scheffé method of multiple comparison was used.

RESULTS

The results of the substance loss experiment are given in Fig. 2. Opalustre® removed significantly more enamel than the other two tested materials at all evaluation times ($p \leq 0.05$). Prema® was statistically not significantly different from the pumice control up to the 30 seconds treatment, but showed a clear tendency for increased enamel dissolution. After 40 seconds, Prema® showed a significantly higher enamel removal capacity compared to the non-acidified pumice control ($p \leq 0.05$).

The roughest enamel surface was found in specimens treated with the Opalustre® slurry during the first 30 seconds ($p \leq 0.05$; Fig. 3). After 40 seconds the surface roughness was not statistically different compared to the other test slurries. But a tendency towards a higher roughening potential was still evident. Findings of the surface roughness measurements were in concordance with the micromorphological analysis showing more affected enamel structure in specimens treated with the acidified abrasive pastes (Fig. 4).

The color measurements showed no significant changes during the treatment periods (Table 2). Positive ΔL values indicated a moderate increase in lucency. Negative values could be observed in the Δa und Δb values, indicating a shift to more green and blue shades, respectively. No statistical differences between the pastes at different evaluation times could be detected.

Concerning substance removal and roughening capacity, the working hypothesis was corroborated for Opalustre®, whereas less untoward effects were observed with. Prema®. The working hypothesis on coulour changes could not be confirmed for any of the tested materials.

DISCUSSION

In the current in vitro study, the commercially available microabrasion products under investigation showed a considerably high tooth substance removal capacity, which was in concordance with the mean surface roughness difference measurements and the micromorphologic analyses.

Loss of tooth substance has been evaluated, but results seem difficult to compare.[6,7] Erosive and abrasive potential during microabrasion depends on several parameters, such as the acid used, its concentration and pH, abrasive medium, time of instrumentation, application mode (i.e., brushes, cups or burs used as slurry carriers), force applied and revolutions per minute (rpm). Unfortunately, these important factors, which influence the investigation outcome, are only poorly described in most studies. The loads applied, for example, were sometimes not mentioned in the Method and Materials section.[5,8] Waggoner *et al.*[4] found an enamel loss of approximately 250 µm in a series of 10 five-second applications using a gentle rubbing motion. Dalzell *et al.*[7], in contrast, found enamel loss of 127 µm using 10 g, 178 µm using 20 g and 213 µm using 30 g pressure for the same treatment period. In the present study, when performing microabrasion for 40 s under standardized conditions (300 rpm in a slow contra angle hand piece using an application force of 100 g), enamel losses were calculated to be 7.9 ± 6.4 µm (pumice), 29.7 ± 25.7 (Prema®) and 53.1 ± 46.5 µm (Opalustre®). In a previous study using Opalustre® we found a surface loss of 134.8 ± 35.5 µm when a pressure of 200g was applied.[9] It has been shown that increasing pressure results in higher substance loss.[7] Croll recommended applying a small load

during the microabrasion procedure. Findings from the latter study group additionally emphasize the difficulty in comparing results based on different operative techniques. However, microabrasion represents an invasive technique. Clinicians must be aware of the remaining enamel thickness when treating discolored areas. Given that enamel thickness is approximately 1 mm, removal of 0.13 mm may be clinically significant, especially in then long run, if treatments are repeated.[10]

Surface roughness has been quantitatively evaluated in only one previous study according to the authors' knowledge.[11] This study investigated the influence of Prema® on enamel and restorative materials. In concordance with the present study it was found that Prema® did not significantly affect surface roughness. There are no data concerning Opalustre® in the literature.

The present report is on the first study, which has evaluated quantitatively color changes after microabrasion under standardized conditions in vitro. Since teeth exhibited no visible discolorations prior to treatment, significant positive changes could not have been expected.[9] On the other hand, possible significant intrinsic untoward color changes due to the microabrasion compound used were not detected. Slight changes in CIELab values could have been derived from careful drying for 5 seconds prior to measurement and the appearance of the etching pattern. However, differences between the microabrasion materials and the pumice control compound, which contained no acid, were not statistically different.

Within the limitations of the present laboratory investigation, the minimal-invasive character of microbrasion could be documented by significant morphological changes of the enamel specimens. Color changes of sound enamel were not found.

CONCLUSION

Microabrasion preparations show considerable abrasive potentials, causing micromorphological surface changes. These materials possess a damaging potential and the risk of creating defects. Polishing of the microabraded and altered surface and concise fluoridation should thus terminate the treatment. Furthermore, the results of this comparative in vitro study disclosed no additional bleaching effect of the microabrasion materials under investigation.

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Tables

Table 1

Specifications of the materials used in this study.

Material (Batch)	**Manufacturer**	**Acid**	**pH**	**Abrasive media**	**Mean particle size (µm)**
Pumice (3226446)	Pumex S.p.A. Porticello, Italy	None	7.1	pumice	30.7
Prema® (Lot 060601)	Premiere Dental PA, USA	1.4% HCl	3.2-3.5	Silicium carbide/dioxide	63.0
Opalustre® (Lot 4GWQ)	Ultradent UT, USA	6.6% Hcl	0.2	Silicium carbide	87.3

Table 2

Mean ΔL, Δa and Δb values and standard deviations (in parantheses) after microabrasion treatment intervals.

	10 seconds	20 seconds	30 seconds	40 seconds
ΔL				
Pumice	4.6 ± 3.9	5.4 ± 3.0	6.5 ± 3..3	6.5 ± 3.2
Prema®	0.1 ± 3.4	2.2 ± 1.1	2.7 ± 1.0	2.2 ± 1.5
Opalustre®	4.9 ± 3.8	3.4 ± 4.1	3.8 ± 4.1	3.1 ± 5.0
Δa				
Pumice	-0.8 ± 0.9	-0.6 ± 0.5	-0.7 ± 0.4	-0.7 ± 0.4
Prema®	-0.3 ± 0.9	-0.6 ± 0.4	-0.9 ± 0.6	-0.6 ± 0.4
Opalustre®	-0.6 ± 0.3	-0.7 ±0.5	-0.6 ± 0.4	-0.3 ± 0.3
Δb				
Pumice	-3.2 ± 3.8	-2.1 ± 1.4	-2.2 ± 1.3	-2.1 ± 1.1
Prema®	-3.5 ± 1.1	-3.1 ± 1.3	-3.2 ± 1.3	-2.7 ± 1.3
Opalustre®	-4.2 ± 1.5	-3.6 ± 1.2	-3.8 ± 1.7	-3.5 ± 1.6

Fig. 1

SEM images of the abrasive slurry particles at a magnification of 200x.

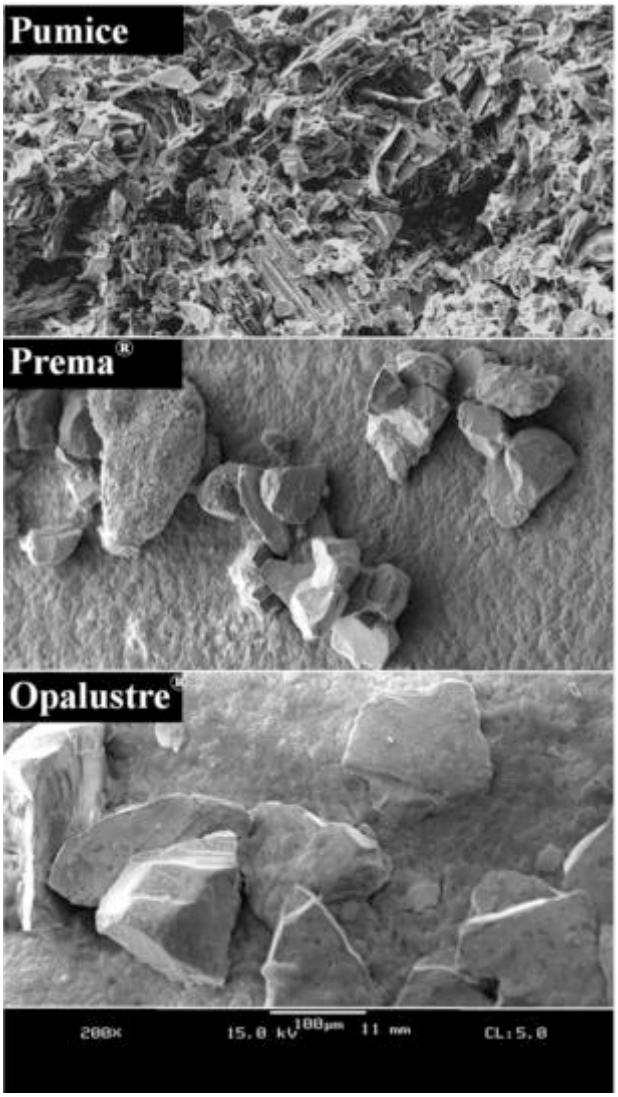

Fig. 2

Box-plots depicting cumulative tooth substance loss in µg Ca^{2+} (box-plot explanation: horizontal bars: medians; boxes: inter-quartile areas; error bars: 10th and 90th percentile; dots: extreme values). N=10 for each group, brackets indicate significant differences between groups $P \leq 0.05$ (ANOVA, Scheffé).

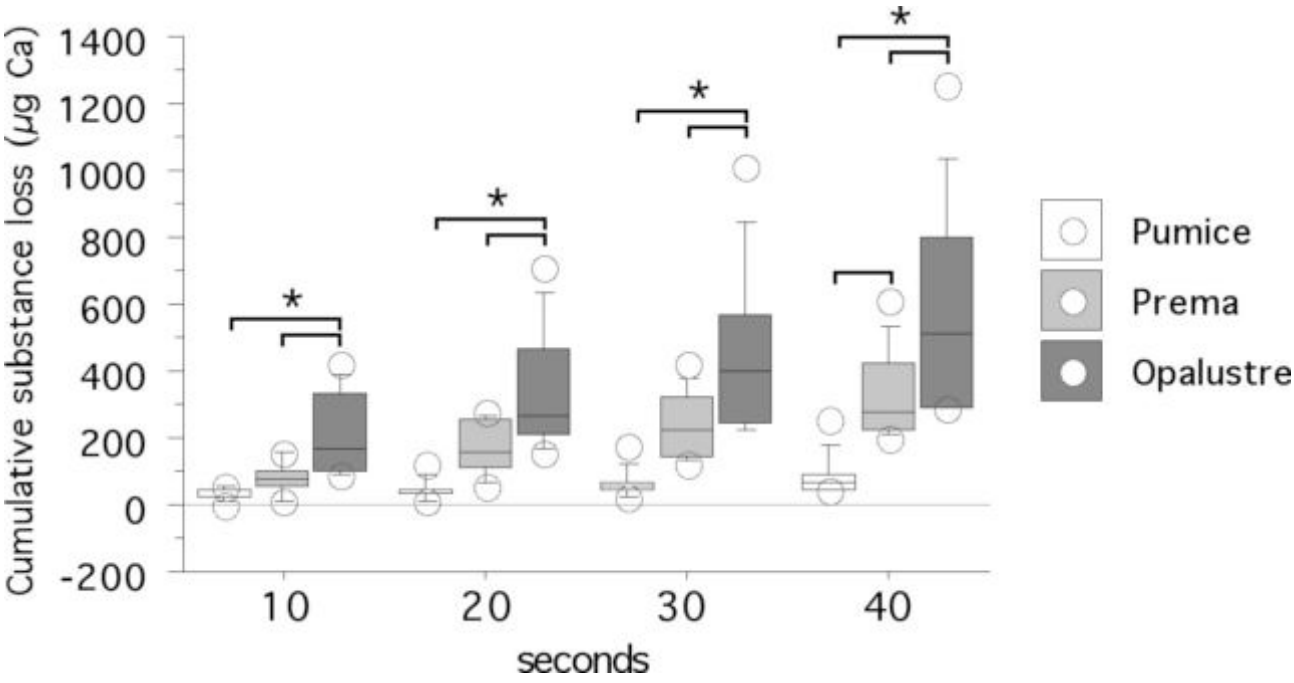

Fig. 3

Box-plots depicting mean surface roughness differences Ra in µm. N=10 for each group, brackets indicate significant differences between groups $P \leq 0.05$ (ANOVA, Scheffé).

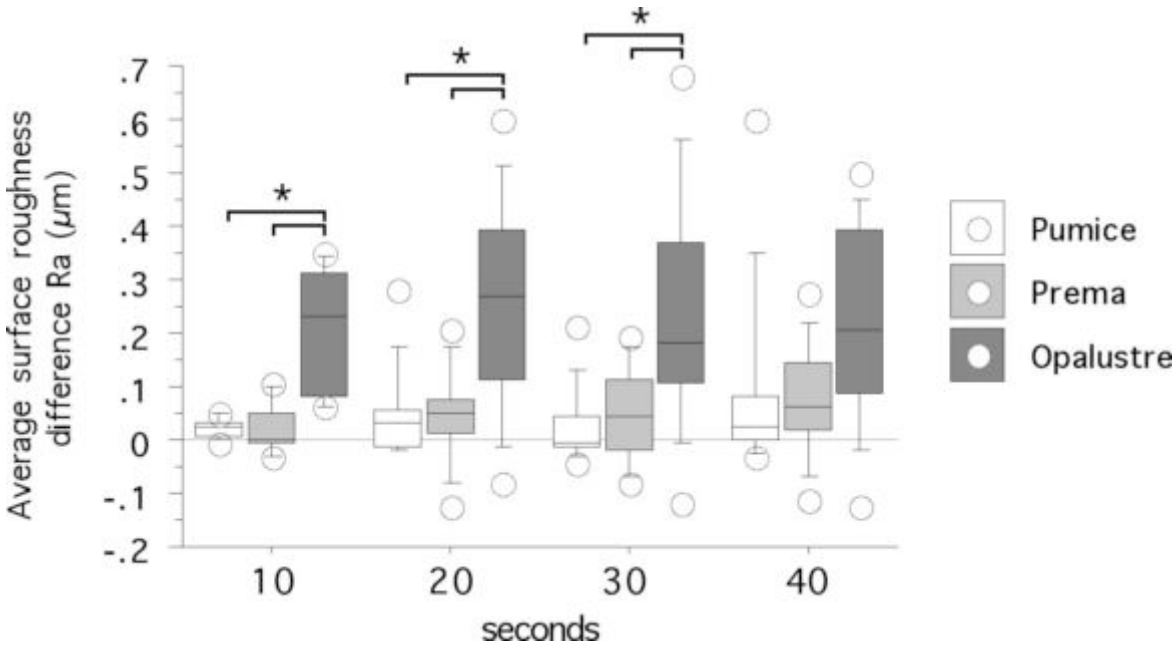

Fig. 4

SEM images of representative tooth samples. Left side: Overview at a magnification of 15x. Right side: detail screen at a magnification 200x. Top: Specimen before treatment, whereas specimens depicted underneath were treated with the abrasive test compounds for 40 seconds. Clearly visible surface alteration area visible in the form of striations (pumice), discernible etching pattern (Prema®) and accentuated roughness (Opalustre®).